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Seed Production of Central Oregon Ponderosa and Lodgepole Pines

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Abstract

Seed production estimates for central Oregon ponderosa and lodgepole pines over periods ranging from 11 to 22 years indicate enough lodgepole pine seeds were produced to provide for a satisfactory crop of seedlings 3 years out of 4 if other conditions were favorable. Ponderosa pine produced only five good seed crops during a 22-year period. Number of sound seeds produced was estimated from seed trap catches. Percent of seeds that were sound was estimated from a cutting test.

KEYWORDS: Seed production, ponderosa pine, *Pinus ponderosa*, lodgepole pine, *Pinus contorta*.

Contents

Introduction

Seed production and dissemination data are necessary for planning natural regeneration of any forest. This kind of information is especially needed for central Oregon lodgepole pine (*Pinus contorta*) because, unlike the Rocky Mountain variety, cones are generally not serotinous and seeds are shed within the first year after cone maturation (Critchfield 1957, Mowat 1960, Trappe and Harris 1958). Furthermore, central Oregon lodgepole pine stands are normally regenerated by natural means, usually shelterwood. The present desire to maintain a continuous forest cover also makes the shelterwood or seed tree method an attractive approach to regenerating even-aged ponderosa pine (*Pinus ponderosa*) stands and increases interest in frequency and size of ponderosa pine seed crops.

To acquire the needed information on size and frequency of seed crops produced by these two pines, studies were begun in central Oregon during 1953. Partial results have been presented by Barrett (1966) and Dahms (1963). This paper contains final results from these studies plus a brief review of the most pertinent literature concerning seed production and its dissemination for ponderosa and lodgepole pines.

Review of Past Work

Lodgepole pine is a prolific seed producer according to Tackle (1965). Good crops are borne at 1- to 3-year intervals with light crops during intervening years. However, average annual seed production varies substantially from place to place and from year to year. Bates (1930), for example, reports an average annual production of 72,992 good[1/] lodgepole pine seeds per acre[2/] on the Medicine Bow National Forest in Wyoming over a 10-year period. None of the crops during this 10-year period reached 200,000 seeds per acre, but only 1 year was a complete blank. During the same 10-year period, the average annual seed production was 320,053 sound seeds per acre on the Gunnison area in Colorado (Bates 1930). During 5 of the 10 years on the Gunnison National Forest study area, there were 200,000 or more seeds per acre and during a 6th year almost that many. During 1 year, more than 800,000 sound seeds per acre were produced. Less than 100,000 seeds per acre were produced during each of the remaining 4 years, but there were no complete blanks. Montana results reported by Boe (1956) indicated an average annual seedfall of 17,500 sound seeds per acre over a 4-year period.

Ponderosa pine produces fewer seeds per crop and fewer good crops than lodgepole pine. Fowells and Schubert (1956) reported 200 or more cones per acre produced 4 years out of 16 in the west side Sierra subregion of California. However, during 7 of the 16 years, less than 50 cones per acre were produced. In terms of number of seeds per acre, this means less than 2,000 sound seeds 7 years out of 16 and a maximum crop of less than 20,000 sound seeds per acre for the best year.

Shearer and Schmidt (1970) reported only two good crops and one fair crop of ponderosa pine seed in western Montana during the 11-year period from 1948 through 1958. The best crop (1958) averaged 135,000 seeds per acre, but the fair crop

[1/] Good seeds as used by Bates means seeds that will germinate under the conditions of a laboratory germination test.

[2/] One acre equals 0.404687 of a hectare.

consisted of only 42,000 seeds per acre. During 3 of the 11 years, no seeds were caught; and on 2 other years, less than 500 seeds per acre were found. Curtis and Foiles (1961) reported three bumper seed crops in central Idaho during the 23-year period from 1936 through 1958. During each of the heavy seed years, more than 200,000 ponderosa pine seeds per acre were produced.

Larger, more vigorous trees of both lodgepole and ponderosa pines produce the most seeds. Bates (1930) divided lodgepole pine trees into dominant, codominant, intermediate, oppressed, and suppressed tree classes, with crowns within each tree class divided into full, average, and small classes. There was a general trend of lesser production from dominant to suppressed trees and from full to small crowns. However, Bates did not consider the trend as strong for lodgepole pine as for some other species.

Dominant ponderosa pine trees accounted for by far the largest share of cones produced by this species (at least 97 percent). Codominants accounted for only 1 to 1.5 percent of all cones produced, while the intermediate and suppressed crown classes accounted for only a fraction of 1 percent of the total (Fowells and Schubert 1956).

Despite the fact that dominant trees accounted for most of the cones produced in Fowells and Schubert's study, not all dominants were seed producers. Among the dominants, the largest crowned, most vigorous trees were the best producers. Size and frequency of cone crops were both correlated with tree diameter. Dominant trees in the 7.6- to 11.5-inch[3/] diameter class averaged only 1 crop in 16 years, while dominant trees larger than 24 inches averaged 10 crops in 16 years.

Foiles and Curtis (1973) presented results from central Idaho that tended to confirm some of Fowells and Schubert's California results. Mature Idaho trees produced more seed than immature trees, and isolated individuals produced better than stand-grown trees.

Percent of seed that was sound was highest during years of heavy seed production and there was also a tendency for sound seeds to fall earlier in the season, according to both Fowells and Schubert (1956) and Shearer and Schmidt (1970).

Seed from ponderosa pine generally falls during late summer and early fall. Curtis and Foiles (1961) reported that the 1958 crop in central Idaho began falling by August 12 and that maximum seedfall occurred between September 10 and 30. They also reported that some seedfall continued through the winter. Fowells and Schubert (1956) reported that seedfall generally occurred during the autumn months. Not all seeds are shed at that time, however. In one instance when traps were left out all winter at Blacks Mountain, only 67 percent of the seed had fallen by the end of November. In another instance on the Stanislaus National Forest, they reported 84 percent had fallen by November. Mowat (1960) reported that by October 22 at elevations up to 5,400 feet[4/] most of the lodgepole pine seeds of the 1954 crop in central Oregon had been shed; but at 5,900 feet, up to 25 percent of the seeds remained in the cones.

Weather obviously had important effects on the development of cone crops; but not all of the relationships are clear, according to Fowells and Schubert (1956). They

[3/] One inch equals 2.54 centimeters.

[4/] One foot equals 0.304801 of a meter.

noted that white fir cone crops were adversely affected by frost during the flowering period. However, they were inclined to believe that the pines were not subject to frost damage in California because of late flowering, citing a study by Roeser (1941) to substantiate their belief. Frost, on the other hand, was cited as the probable reason for failure of the 1919 lodgepole pine seed crop on the Medicine Bow National Forest, while the same year a bumper crop was produced on the Gunnison National Forest in Colorado (Bates 1930).

Sorensen and Miles (1974) cited definite evidence of frost injury to developing conelets of both ponderosa and lodgepole pines in the central Oregon area. Ponderosa pine was much more severely damaged than lodgepole. They suggested differential frost resistance of conelets of the two pines was probably another mechanism favoring lodgepole pine over ponderosa pine in frost pocket situations.

Freezing damage to lodgepole pine conelets in an area where lodgepole and ponderosa pines grow together suggests that damage might frequently be severe in frost pocket situations where only lodgepole pine can survive. It may well turn out that basin or frost pocket areas on central Oregon pumice are difficult to regenerate not only because of germination and seedling survival problems but also because lodgepole pine seed crops may be less frequent and smaller in size. Cochran[5/] and other foresters believe they see less frequent cone crops in frost pocket situations.

Pine seeds are not dispersed in substantial numbers very far from the tree that produced them. For example, Boe (1956) reported that number of lodgepole pine seeds dispersed 1 chain[6/] out into a clearcut was only 14.3 percent of the number that fell under the timber. At 2 or 3 chains, only 8.6 percent of the under-timber-catch was found.

Barrett (1966) found that ponderosa pine seeds at 2 chains represented 24.6 percent of those caught at timber edge and at 6 chains, 7.5 percent. It is probable that Barrett's "at timber edge" and Boe's "under the timber" are not entirely comparable.

Study Methods

There were two studies, one at Pringle Falls Experimental Forest and the other on the Winema National Forest just east of Crater Lake National Park. At both locations, traps were used to catch seeds and thus provide estimates of number of seeds reaching the ground. Cutting tests were used to distinguish sound seeds from nonsound.

The Pringle Falls study was begun in 1953.[7/] A mature ponderosa pine stand, an immature, even-aged ponderosa pine stand (age 100 years in 1953), and a mature lodgepole pine stand were sampled--10 traps, each 2 by 3 feet, in the mature ponderosa pine stand, 5 in the immature stand, and 5 in the lodgepole pine stand. Later (1966) an additional five traps were added in the immature ponderosa pine. Seed traps were mechanically spaced along a straight line in each of the three stands. The goal of this study was to estimate size and frequency of seed crops for ponderosa and lodgepole pines.

The lodgepole pine seed traps were

[5/] Personal communication with P. H. Cochran, soil scientist, Silviculture Laboratory, Bend, Oregon.

[6/] One chain = 20.1168 meters.

[7/] This study was designed, installed, and maintained by Edwin L. Mowat until his retirement in 1963.

located in a nearly pure lodgepole pine stand in a *Pinus contorta/Purshia tridentata* community growing in the Pringle Falls Research Natural Area. Other plants found in the sparse understory include western needlegrass (*Stipa occidentalis*), Ross's sedge (*Carex rossii*), bottlebrush squirreltail (*Sitanion hystrix*), and strawberry (*Fragaria cuneifolia*) (Franklin et al. 1972). Elevation is about 4,300 feet.

The old-growth ponderosa pine sampled for seedfall was also located in the Pringle Falls Research Natural Area. Traps were located in a *Pinus ponderosa/Purshia tridentata* plant community at an elevation of 4,500 feet.

The ponderosa pine seed traps in the young-growth stand are located in a *Pinus ponderosa/Ceanothus velutinus* community on the Lookout Mountain addition to the Pringle Falls Experimental Forest. This is a seral community growing on an *Abies concolor/Ceanothus velutinus* climax association. Elevation is 4,700 to 5,000 feet.

The Winema lodgepole pine seedfall study, started in 1959, was aimed more at estimating dispersal of seed into clearcut areas from surrounding timber edges. Lines of seed traps started 1 chain from the timber edge under the timber and extended into a clearcut area at 1, 3, 5, and 7 chains from timber edge in nearly north, south, east, or west directions. A given line of traps consisted of 4 traps under the timber and 4 others at the 1-, 3-, 5-, and 7-chain distances into a clearcut for a total of 20 traps per line. From 4 to 6 such lines were operated during the 11 years the study was in operation, except 1959 when only 16 traps were used.

The Winema study was located in a predominantly mature lodgepole pine stand growing in a *Pinus contorta/Purshia tridentata-Ribes cereum* plant community.

Results

PRINGLE FALLS STUDY

Size and Frequency of Crops

Lodgepole pine definitely produced larger and more frequent seed crops than ponderosa pine (fig. 1) at Pringle Falls. During the 16 years with available records from 1953 through 1971, lodgepole pine produced nine crops with 200,000 sound[8/] seeds per acre or more. The largest crop was in 1954 when an estimated 900,000 sound seeds per acre were produced. There were only 3 years during the period when less than 50,000 seeds per acre were produced, and no total failures.

The old-growth ponderosa pine in contrast produced only three measured crops of 200,000 seeds per acre or more for certain during the 19-year period from 1953 through 1971. However, 1968, a known good seed year, also probably exceeded 200,000 (fig. 2); but the records were destroyed. A fifth good crop (1974) also appears assured. Thus during the 22-year period 1953 through 1974, there were five good ponderosa pine seed crops.

Differences between old-growth and young-growth ponderosa pine seed production were minor and almost certainly could be accounted for by sampling variation. The largest seed crop produced by the immature stand was 663,000 sound seeds per acre. Good seed crops occurred in both old-growth and immature stands the same years.

[8/] As determined by a cutting test of all seeds that looked at all normal. This is undoubtedly an overestimate of the number of seeds that will germinate.

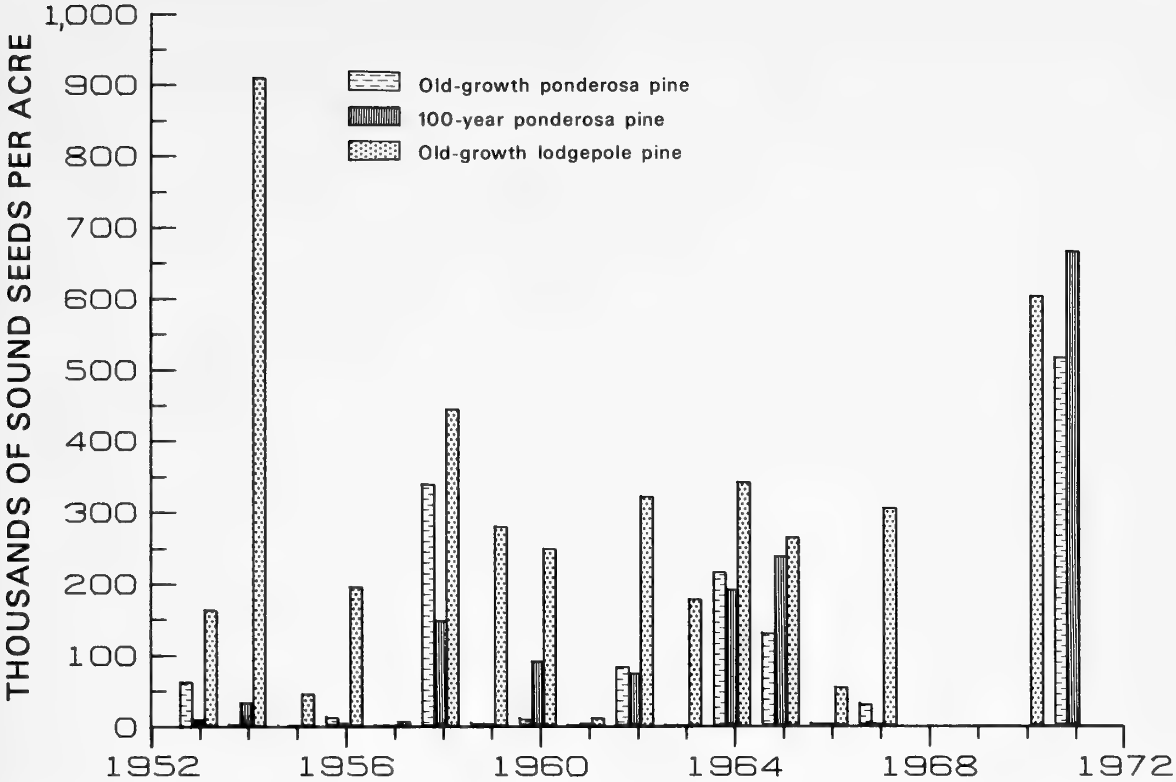
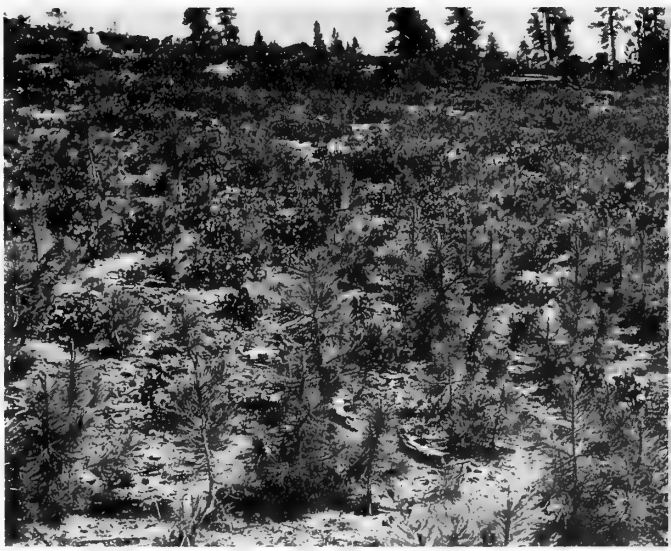


Figure 1.--Sound seeds per acre by year for old-growth ponderosa pine, 100-year ponderosa pine, and old-growth lodgepole pine. Pringle Falls study (data missing for 1968, 1969, 1970, and 1971 were destroyed by the 1974 fire at the Silviculture Laboratory in Bend).

Figure 2.--These 5-year-old seedlings on Pringle Butte originated from the 1968 seed crop. Although no records remain to show size of that crop, the resulting seedling catch on this 19-acre clearcut clearly demonstrates the 1968 seed crop was a substantial one. Site preparation, done in the early spring of 1969 as a prelude to planting, apparently buried many seeds to about the right depth. Logging in late winter (early 1969) meant seeds from all of the trees growing on the area had been showered down on the clearcut patch prior to cutting.



Time of Seedfall

Lodgepole pine seedfall was 46 percent complete by early October. An additional 29 percent was released by early November, and the remaining 25 percent came down by the following summer.[9/] There are some substantial deviations from the average figures during individual years. For example, seeds were 89 percent shed by October 9 in 1960, but only 14 percent shed by October 1 in 1959, both good seed years.

Ponderosa pine did not, on the average, release its seed quite as early as lodgepole pine. Of the seed produced by the old-growth and immature stands, 38 and 39 percent, respectively, had been shed by early October. An additional 44 percent was shed by early November. Between early November and summer, 18 and 17 percent of seed from old-growth and immature stands came down. These average figures might seem comforting to someone who would like to do a site preparation job with fire in late September or even early October. However, there is a great deal of variation about the average. By October 7, for example, 89 percent of the large 1958 crop had been shed.

9/ These figures are based on total seedfall for all of the years involved. Consequently the average is weighted in favor of the heavy seed crops as it should be.

Soundness of Seed

Lodgepole pine seed averaged 74.7 percent sound on the basis of a cutting test. There was a tendency for a higher percentage of seeds to be sound during the fall season when seedfall is normally heaviest. Seed that had fallen by early October was 75.5 percent sound, that which fell in October and early November was 73.0 percent sound, but that which fell during the following winter, spring, and early summer was only 55.2 percent sound. These findings tend to agree with results published earlier by other investigators (Fowells and Schubert 1956, Shearer and Schmidt 1970).

Sound seed percentage was also greater during years of abundant lodgepole pine seed production (fig. 3). The relationship between soundness of seed and size of seed crop is significant well beyond the 1-percent

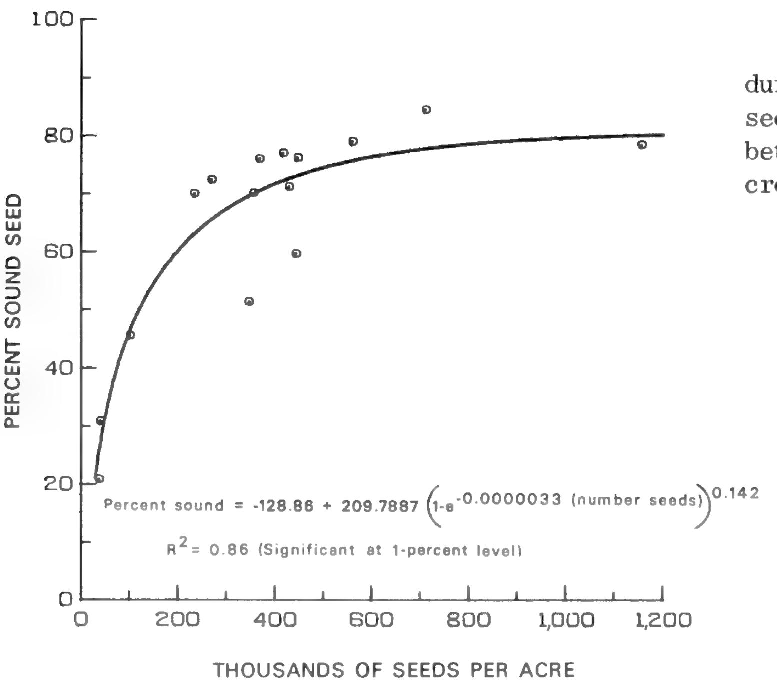


Figure 3.--Percent of seeds that were sound as related to crop size. Lodgepole pine, Pringle Falls Research Natural Area.

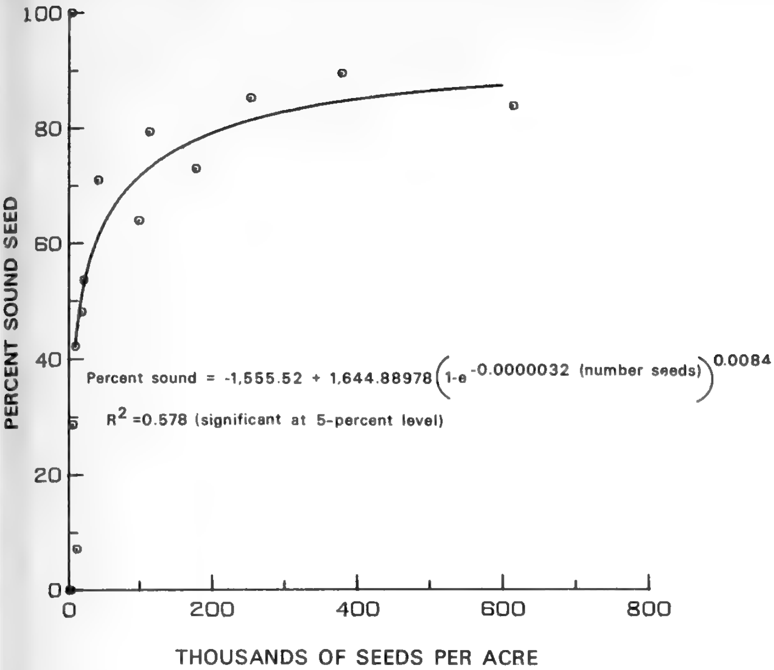


Figure 4.--Percent of seed that was sound as related to crop size. Old-growth Ponderosa pine, Pringle Falls Research Natural Area.

level. None of the crops with 100,000 seeds per acre or less averaged 50 percent sound. All of the larger crops were more than 50 percent sound.

Ponderosa pine seed produced by the old-growth stand averaged 80.8 percent sound and that from the immature stand, 86.6 percent. Soundness also tended to relate to time of seedfall and size of crop, as was also true of lodgepole pine seed; but the relationships were not quite so strong. Seeds shed by early October in the old-growth stand were 84.3 percent sound, those shed between early October and early November were 83.7 percent sound, and those falling between early November and the following late spring or summer were 68.6 percent sound. Percents of seeds that were sound from the immature stand were 85.9, 91.4, and 78.1 for equivalent periods. Sampling variation almost certainly can account for the differences between the two stands.

There is a significant relationship between total number of seeds produced and percent sound in the case of the old-growth stand (fig. 4). However, in the case of the immature stand, no relationship could be demonstrated.

WINEMA STUDY

Size and Frequency of Crops

Lodgepole pine produced five crops of 200,000 or more sound seeds per acre on the Winema study area during the 11-year period from 1959 through 1969 inclusive. The largest crop was in 1962 when an estimated 854,500 sound seeds per acre were produced. Two crops, 1961 and 1966, consisted of an estimated 14,000 and 14,300 sound seeds per acre. The remaining 4 crops ranged from 56,600 sound seeds in 1967 to 178,200 per acre in 1959 (fig. 5).

Size of seed crops at Pringle Falls and on the Winema National Forest were correlated to a considerable extent. Seed crops at both locations were near failures in 1961 and 1966. However, in 1962 the largest crop of all on the Winema (854,500 sound seeds) was matched by only about 320,000 sound seeds at Pringle Falls.

Time of Seedfall

The largest percentage of seeds fell during October and early November. Overall, 36.9 percent had fallen by early October, an additional 40.8 percent fell

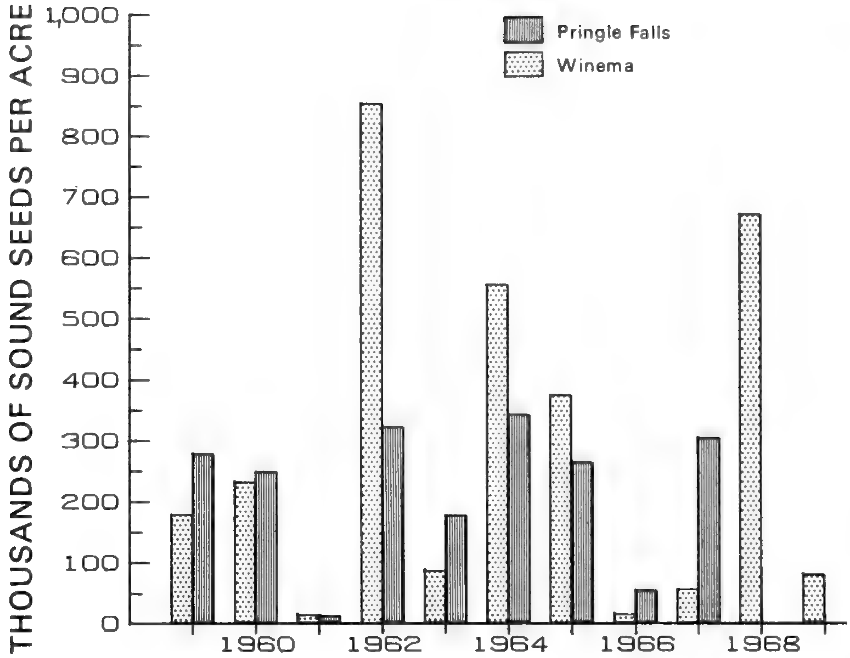


Figure 5.--Number of sound Lodgepole pine seeds per acre on the Winema and Pringle Falls areas.

by early November, and the remaining 22.3 percent fell by the following summer.

There was considerable variation in time of seedfall from year to year. The bumper crop of 1962 was only 5.5 percent down by early October; but in the case of the second largest crop, 1968, 65.8 percent had fallen by the same date.

Seedfall on the Winema area was slightly behind that at Pringle Falls. The greater elevation of the Winema area, about 5,000 feet as compared to about 4,300 feet at Pringle Falls, could reasonably account for the difference.

Soundness of Seed

The Winema lodgepole pine seed averaged 79.3 percent sound overall, compared with 74.7 at Pringle Falls, but there was considerable variation from year to year. The range was from 40.1 percent sound in 1966 to 86.7 percent in 1964. Consequently, differences between the two areas are reasonable.

There was a definite tendency for percentage of seeds that were sound to be higher when a larger crop of cones was produced (fig. 6). The correlation between percent sound and size of crop is statistically significant at the 5-percent level.

Percentage of seeds that were sound was higher from the October and November collection dates than from the summer collection. Seeds averaged 78.3, 84.4, and 72.6 percent, respectively, for the three collection dates. Although the differences do not seem large, seeds from the summer collection had a lower percentage of seeds that were sound than from either the early or late fall dates every

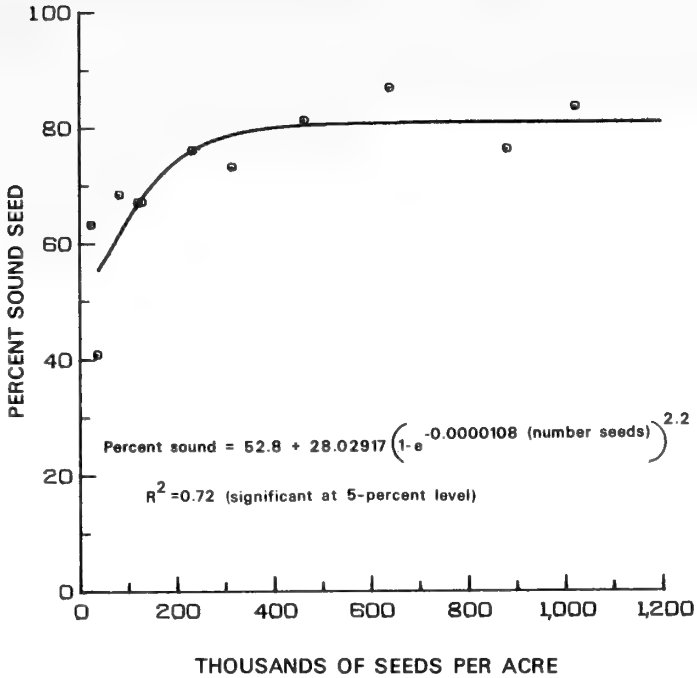


Figure 6.--Percent of seed that was sound as related to crop size. Lodgepole pine, Winema study.

one of the 11 years, convincing evidence that there is a difference.

Dissemination of Seed Into Clearcut Areas

As distance from the timber edge increased, number of seeds disseminated into clearcut areas from surrounding timber edges fell off very rapidly (fig. 7). At 1 chain, number of sound seeds ranged from 3.2 to 16.2 percent of the number found under the timber. At 3 chains, the percentage dropped to 0.1 to 1.8 percent of the catch under timber.

Wind direction during seedfall appears to have had some effect on distance seed are disseminated into a clearcut from a

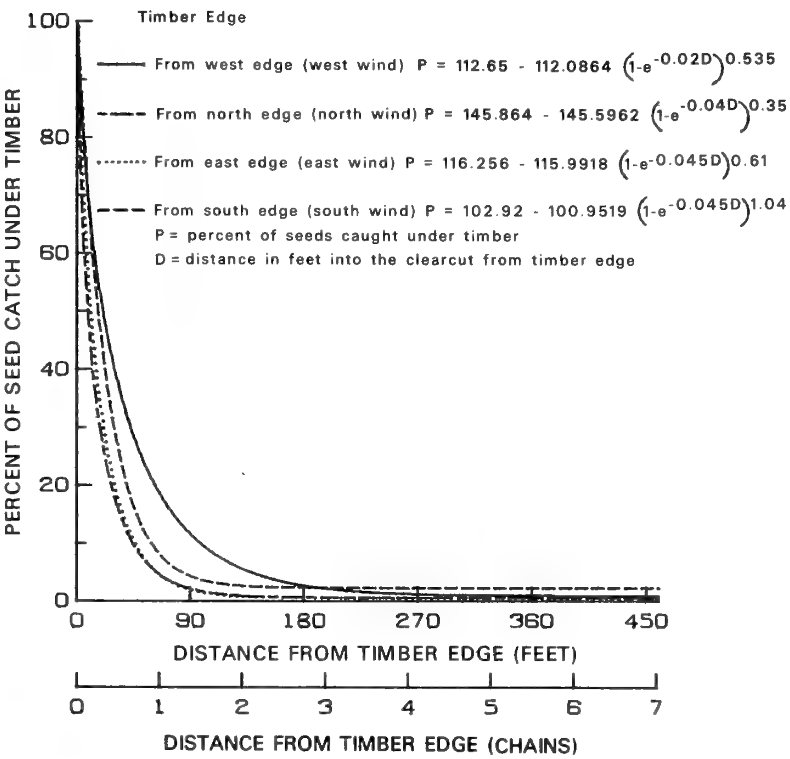


Figure 7.--Dissemination of seed into clearcut patches from surrounding timber edges. (For purposes of this graph, the seed catch 1 chain back in the timber was treated as though it occurred at timber edge. This probably has the effect of overestimating seedfall from timber edge to 1 chain out.)

timber edge. More than 16 percent of the seedfall under timber was found 1 chain from the west edge of a clearcut (west wind) as contrasted with only 3.2 percent 1 chain from the east edge (fig. 7).

In 1963, two additional trap lines were installed in different clearcut areas to provide some replication. One of these lines extended into the clearcut from a south timber edge (south wind) and the other from a west edge. Dissemination from the south edge amounted to 13.6 percent and 2.7 percent of the under timber crop at 1- and 3-chain distances, respectively, into the clearcut. Corresponding west edge figures were 8.6 and 1.7 percent, respectively.

Differences between the two sets of south edge and west edge data are not surprising. The first south edge figures--4.4 and 1.3 percent of the crop under timber at 1 and 3 chains from timber edge, respectively--came from a 60-year-old stand that was slightly down slope from the cleared area. The second set (13.6 and 2.7 percent at 1 and 3 chains, respectively) came from 120-year-old timber that was somewhat taller than the 60-year-old trees. Furthermore, the older, taller timber stood on sloping ground that rose slightly above the cleared area. Thus topography and height of timber appear to explain the difference.

Differences between the two west edge lines (14.7 and 2.7 percent of crop under timber at 1 and 3 chains, respectively, into the clearcut versus 8.6 and 1.7 percent) appear to be largely caused by slight differences in topography. However, sampling variations undoubtedly also play a part.

Discussion and Application

Size and frequency of seed crops produced by ponderosa and lodgepole pines contrast sharply. At Pringle Falls, lodgepole pine produced nine seed crops with 200,000 or more sound seeds per acre out of 16 years. There were 3 additional years with more than 150,000 sound seeds per acre. If we assume 150,000 sound seeds per acre is enough to produce an adequate crop of seedlings, given favorable germination and survival conditions, lodgepole pine produced 12 adequate seed crops out of 16 years. Similarly ponderosa pine produced five adequate seed crops in 22 years.

Seed production of lodgepole pine in low lying frost pockets deserves further investigation. The frost damage reported by Sorensen and Miles (1974) suggests that seed crops might be smaller and less frequent in frost pockets. However, it takes more than casual observation to establish such a relationship. Lodgepole pine cones are not easily seen unless they are abundant. Mowat[10/] for example, had this to say about the 1953 lodgepole pine cone crop in the vicinity of the seed traps: "Cone crop was first thought to be very light in this area--a few cut-off cones were seen on the ground, but very few on the trees. The catch of seed suggested that this observation may not have been thorough enough, and closer inspection revealed that the crop should rate at least 'light', as there were a fair number of cones on a few trees and a few on many of the best producers. One must look quite closely in this stand, as cones are relatively small and production is mostly at the tops of trees." Estimated seed production based on the catch in traps was

10/ From a memorandum with file designation RS - NW, REGENERATION, seed studies, seedfall on Pringle Falls E. F., D40 entitled "Notes for data file on 1953 cone crop," dated 10/2/53 by Edwin L. Mowat. This memorandum is on file at the Silviculture Laboratory, Bend, Oregon.

approximately 160,000 sound seeds per acre that year. If a careful observer like Mowat could so badly underestimate the lodgepole pine seed crop, there is a good possibility that most other foresters could also.

Opportunities to provide seed for natural regeneration of lodgepole pine obviously occur much more frequently than for ponderosa pine. However, with a shelterwood approach where a substantial overwood is reserved, waiting several years for a ponderosa pine seed crop could be acceptable practice. Where a long wait between logging and a seed crop occurs, another site preparation job may be necessary just before or immediately after seedfall but before spring germination begins.

Selection of trees to save as a seed source in a shelterwood type cut should logically follow nature's scheme. The largest, most vigorous, full-crowned dominants are the best genetic base for the next crop; and at the same time, they are the best seed producers. Fowells and Schubert (1956) found that approximately 97 percent of the ponderosa pine seed in the west side Sierra type was produced by dominant trees. Similarly, Bates (1930) found a strong relationship between seed production and vigor and dominance of lodgepole pine. Consequently, if a reasonable shelterwood consisting of the largest, most vigorous trees is retained, the bulk of the stand's seed producing capacity will also be retained in either ponderosa or lodgepole pine stands.

The question, how many seeds are required to produce an acceptable crop of seedlings, is not well answered. Foiles and Curtis (1973) reported in one instance it took 55 seeds to produce one established seedling on scarified soil.

Not all years are favorable for natural regeneration. Cochran (1973) points out, "A series of events is necessary for natural regeneration.... Germination must be favored by warm and moist surface soils, daily surface temperature variation must be moderate, seedlings must survive summer drought, and weather conditions must prevent severe frost-heaving the fall after germination and the next spring." Clearly, some years more nearly meet these conditions than others. Cochran (1973), for example, reports germination of lodgepole pine seed ranged from 0.7 percent in 1972 to 45.5 percent in 1971 on one area. Furthermore, squirrels and other small mammals cut cones and eat seeds. Consequently, a large number of seeds, perhaps as many as 150,000 per acre, are needed to assure an adequate seed supply assuming other conditions are reasonably favorable.

Conditions for germination of seeds and survival of the resulting seedlings can also reasonably be expected to vary from one habitat type to another. Cochran (1973) did not report encouraging results from his studies in the lodgepole pine flats. However, the 1968 and 1971 seed crops produced an abundance of ponderosa pine seedlings[11/] on Pringle Butte in the ponderosa pine/snowbrush community where the soil was well scarified (fig. 2).

Number of seeds dispersed into clear-cut patches falls off rapidly as distance from timber edge increases. Only 2 or 3 percent of the lodgepole pine seed catch under timber falls at a distance of 2 chains from timber. Furthermore, the tremendous range in temperature of pumice soil seedbeds and the tendency for those extremes to be greater in larger clear-cuts (Cochran 1969a, 1969b) makes natural regeneration of large openings

[11/] Unpublished data on file at the Silviculture Laboratory, Bend, Oregon.

on pumice flats unlikely. Even in favorable habitat types, increasing the distance seed must fly beyond 2 chains substantially reduces prospects for natural regeneration.

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The mission of the PACIFIC NORTHWEST FOREST AND RANGE EXPERIMENT STATION is to provide the knowledge, technology, and alternatives for present and future protection, management, and use of forest, range, and related environments.

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2. Development and evaluation of alternative methods and levels of resource management.
3. Achievement of optimum sustained resource productivity consistent with maintaining a high quality forest environment.

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